

Prehabilitation: Preparing Young Athletes for Sports

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Great athletes may be born and not made, but I believe that there are many with great potential who succumb to non-contact injury through poor training habits, or as a result of correctable biomechanical imbalances. Preparing an athlete for sports requires medical and orthopedic evaluation, assessment of fitness for competition, and education in the principles of proper training. Because few individuals have access to a comprehensive sports medicine center, primary care physicians should familiarize themselves with the principles of prehabilitation to help young athletes prevent injury and realize their full potential.

Introduction

I ascribe to the belief that great athletes are born, and not made [1]. If you consider the myriad of complex physiologic and neuromuscular variables that define performance, it's not hard to draw that conclusion. But I also believe that many potentially great athletes never have an opportunity to demonstrate their superior genetics, because of repeated noncontact injury. Coached by well-meaning parents with no particular expertise in proper form or technique, young athletes are susceptible to improper training, correctable biomechanical problems, and burn-out [2]. Prehabilitation is not a performance enhancement program, but rather a system of evaluating and educating young athletes, to reduce the risk of injury. It includes both static and dynamic assessment of flexibility, strength, and biomechanics, in addition to education in the principles of basic training and injury prevention.

Injuries are classified as developmental (scoliosis), environmental (altitude), metabolic (heat illness), traumatic, or overuse (repetitive motion). The most common (70%) of all injuries, and certainly the most preventable, are those that occur with overuse [3]. In addition to repetitive motion they always involve some form of

training error, or biomechanical imbalance, which must be corrected for treatment to be successful. If the cause is determined during a preparticipation sports evaluation, athletes may actually be able to prevent a noncontact injury. Therefore, practitioners should include a discussion of the athlete's training habits, in the sports-oriented medical history, and address biomechanical issues during the musculoskeletal examination.

Advanced evaluation includes analysis of complex motion, such as pitching mechanics, or swim stroke. Because most young athletes don't have access to a comprehensive sports medicine center, it is incumbent upon primary care physicians to understand the fundamentals of biomechanical assessment, functional movement screening, and exercise physiology. Applying these skills in the preseason examination, and developing a network of physical therapists or coaches with expertise in specific sports, could help a great many young athletes to develop their full potential.

Evaluation

Preparticipation physical examinations have been somewhat controversial, largely due to a misunderstanding of their purpose [4]. They should not be considered a routine health examination for adolescents, nor a brief and inadequate "rubber stamp" clearance to satisfy risk-managers. They are an assessment of a young athlete's preparedness to meet the physical and psychologic demands of sports. Participation has become so ubiquitous, and increasingly competitive, that evaluating young athletes requires a thorough examination. In that respect, the history and physical should be sport specific, addressing risk factors for sudden death, conditions that have a potential to limit performance, and training errors.

The examination should be done annually to reflect the changing biomechanics of growth in this population, and 6 to 8 weeks before training or competition, to allow time for rehabilitation of old injuries [5]. Fifteen to 20 minutes of office time are required, but a careful mass-screening process is much more effective. Because musculoskeletal evaluation obviously consumes the most time, having multiple stations with therapists or trainers involved, is more efficient. I believe that all young athletes, regardless of skill level, deserve a simple biomechanical assessment, including

functional movement screening, as part of their pre-participation physical examination.

History

The American Academy of Pediatrics maintains one of the most complete lists of limiting conditions for sports, and those in which exercise is contraindicated [6•]. Although not universally accepted, I believe it takes into account that we are dealing with young athletes, and not professionals. Three questions with the greatest predictive value for sudden death in sports are a history of fainting with exercise, multiple episodes of fainting, and sudden death in a family member under age 50. The history should also inquire about treatable medical conditions that may limit performance, such as exercise-induced bronchospasm, anemia, and frequent cramping. Individuals with one gene for cystic fibrosis (1/31 whites) sweat unusually large amounts of sodium, and are predisposed to cramps or exercise-associated hyponatremia [7].

I feel the most important aspect of a sports history is to elicit a young athlete's possible training errors. Every practitioner should understand the basic principles of exercise physiology, and then utilize the expertise of a coach or trainer, when more sport-specific issues arise. The two most common errors represent opposite ends of a spectrum. Many young athletes begin the season unprepared to meet the physical demands of their sport, whereas others try to develop fitness in such a short period of time that they violate the "rule of twos" (too much, too hard, too fast, too soon). Young athletes, especially those with promise, suffer from external pressure to compete on several teams in succession, usually without time to recover between sports seasons. Similarly, strength athletes such as football players are often asked to wrestle, which puts joints fatigued by their primary sport in jeopardy of serious injury. Finally, parents and coaches, realizing the possibility of a scholarship or career in sports, succumb to the belief that their children must train like professionals. In fact, emulating the training habits of an elite athlete, before developing adequate strength and coordination, is almost certain to result in injury. Briefly reviewing an athletes' training log may provide some insight into these common errors. Because some sports involve complex technique (swim stroke), which predisposes to unique injuries (swimmer's shoulder), it is useful to inquire about whether an athlete has attended any camps or received other individualized instruction.

Physical examination

Most family physicians perform a thorough medical evaluation of athletes, but pay little attention to the musculoskeletal system. For that reason, potentially limiting conditions, including unrehabilitated injuries, are often overlooked. A good, basic musculoskeletal examination includes testing all joints for range of motion, and stability. Major landmarks should be palpated for tenderness, then flexibility and strength of all muscle groups tested.

Certain sports place specific demands on joints (eg, knee and ankle in football, shoulder and elbow in baseball), so additional evaluation is warranted in these athletes. Injuries that have not been fully rehabilitated during the off-season should be addressed, and a treatment plan formulated. Finally, a screening biomechanical assessment should be done. This has the greatest impact on preventing noncontact injury, but unfortunately is rarely performed by primary care physicians. Many good resources are available that present a thorough but relatively simple examination of the musculoskeletal system [8].

Biomechanical assessment

Begin your evaluation with the athlete standing, arms at his or her sides. Approach from behind, and place finger tips on the shoulders then pelvis to assess spinal alignment and limb length. If both the shoulder and hip on one side appear to be higher than the other, suspect a leg-length inequality. Palpate the sacroiliac joints for tenderness, and assess the arches, to exclude sacroiliac rotation or unequal pronation as a possible cause. When the shoulder and hip inequality is on opposite sides, check for scoliosis by having the athlete bend forward. The diagnosis is confirmed if a rib hump appears, usually involving the right posterior chest. There is no support in the literature for the common misconception that patients with a left thoracic curve should be screened for cardiac abnormalities [9]. Viewing the athlete from the front, once again assess the arches, and look for malalignment of the knees (valgus or varus deformity) or patellae. The Q-angle is measured between a line drawn from the anterior superior iliac spine through the center of the patella, and a similar line that extends upward from the tibial tubercle. Greater than 10° to 15° is abnormal, and may cause patellar maltracking, which manifests as retropatellar pain syndrome. Remember that excessive pronation (easily correctable) results in internal tibial rotation, and aggravates Q-angle abnormalities. Complete the knee examination with an assessment of patellar mobility.

With the athlete prone, and knees flexed 90°, measure internal and external rotation of each hip, normally 45°. Although not correctable, abnormal hip rotation can predispose to maltracking. In that same position, flex the ankle to 90°, and assess the thigh-foot angle. Normal alignment is 5° to 10° of external tibial torsion. With the athlete supine, shoulder range of motion can also be assessed. Abduct the arm to 90° and measure the total excursion, which is 180°. It is widely accepted that the increased external rotation seen in the dominant arm of throwing athletes, comes at the expense of internal rotation [10]. Repeated throwing can result in a tight posterior capsule, further limiting internal rotation, and reducing the mobility to less than 180°. When this internal rotation deficit exceeds 25° (ie, total excursion < 155°), the athlete is at risk for a superior labral tear (SLAP lesion) [11•]. I have the athlete perform an active straight-leg raise while

he or she is supine so I can assess functional flexibility in the hamstrings. Lack of flexibility is one of the leading causes of noncontact injury in this age group.

Assess the athlete's feet while seated. Place a thumb under the metatarsal heads, and lightly press the ankle up into 90° of flexion (neutral position). Stabilize the subtalar joint by wrapping your other hand around the Achilles tendon, with the thumb and middle finger placed between the malleoli and talus. When observed in the frontal plane, a line through the metatarsal heads should be perpendicular to the tibia. If not, it usually slopes down toward the little toe, indicating a varus deformity. Excessive pronation (assessed with the athlete standing) can usually be corrected with a proprietary orthotic, but in the case of forefoot varus, a custom device is necessary.

Functional screening

After a static biomechanical assessment, all athletes should then be evaluated for core stability and functional strength. Many systems have been developed to identify those athletes at risk of nonscontact injury, including the Reebok University 5-point movement screen [12], and Gray Cook's Functional Movement [13]. The following program was adapted from many of those sources, and consists of five simple movements to evaluate flexibility, strength, and balance. During each test an athlete is observed for smooth, coordinated motion, and any lack of symmetry should prompt a more detailed evaluation. All of these maneuvers can also be incorporated into a strength-training program.

Plank

In a prone position, the trunk and legs are held completely straight, supported on the elbows placed shoulder-width apart. Forearms extend out front with palms flat, and ankles are held at 90°. Maintaining this position for at least 1 minute demonstrates acceptable static core strength.

Bird dog

Start in the quadruped position, with shoulders and hips flexed to 90°, supporting the trunk on hands and knees. Maintaining balance, lift a hand and knee on the same side, then extend the arm in front and leg behind, until they form a straight line. Return to the starting position, then lift the hand and knee flexing at the shoulder and hip, until the elbow touches the knee. Watch for balance and smooth motion as the athlete performs this test of rotational core strength on each side.

Squat

The athlete performs a simple deep squat, with the elbows straight, and arms held out in front, parallel to the ground. The feet should be shoulder width apart, and knees remain within that plane. I have the athlete repeat the maneuver with arms overhead to test balance. Dor-

siflexion of the ankle, flexion of the hip and knee, and concentric quadriceps strength are assessed.

March

Stand with the feet shoulder width apart, then transfer the weight to one leg while flexing the opposite hip, and raising that knee as far as possible. Alternate side to side for a few repetitions, arms overhead, then arms in front. Watch for smooth motion, and a level pelvis in this test of balance, knee and hip mobility, and sacroiliac joint function.

Lunge

Start with feet shoulder width apart, arms held out in front at 90°. A piece of tape is placed on the floor in front of the athlete, at a distance equal to the length of the tibia. Taking a step forward, the athlete places his or her heel on the tape, then slowly lowers the trunk until the back knee touches the ground. Returning to the starting position, they then repeat with each leg, two or three times. This is a test of hip flexor tightness, eccentric quadriceps strength, and flexibility at the hip, knee, and ankle.

Advanced testing

More advanced testing is beyond the expertise of most family physicians, but an understanding of these techniques will help guide referral, and ultimately benefit their patients. Training is very sport-specific, so comprehensive evaluation must take into account technical aspects of each sport. Individualized assessment should include a more accurate measurement of specific muscle strength, and development of a custom weight-training program. In some sports, such as cycling, ergonomic evaluation (bike fit) complements the biomechanical assessment [14]. Equipment fit is such an important part of every athlete's comfort and safety, that it is almost essential to network with athletic trainers who have a working knowledge of particular sports. When evaluating endurance athletes, VO₂max testing or a lactate profile may help to guide future training [15••]. Although most are familiar with performing gait analysis, other complex motions such as pitching mechanics or swim stroke can be digitally recorded in two or three dimensions. A coach or trainer with expertise in the particular sport then analyzes the data, and provides feedback to the athlete and his or her parents. Finally, participants in contact or collision sports should undergo some form of baseline neuropsychologic testing, to guide treatment in the event of a head injury. Although normative data are helpful, it is much more powerful to compare an injured athlete's profile against his or her own baseline. Several computer-based programs are available, including ImPACT (Immediate Postconcussion Assessment and Cognitive Testing) [16], HeadMinders Concussion Resolution Index (New York, NY) [17], and CogSport (CogState, Melbourne, Australia) [18].

Education

One of the best ways to prevent injury is to identify and correct training errors before they become problematic. A working knowledge of training principles is essential not only for the athlete, but also the practitioner who must obtain an accurate history, and interpret that information. At the most elementary level, training consists of simply stressing a system, then allowing for rest and recovery, so it can adapt to a higher level of function. It's how the stresses are applied that determines what form of training will occur. The two main types involve either short bursts of intense activity followed by rest (anaerobic), or longer sessions of endurance exercise (aerobic). Although the training for each one is somewhat specific, the basic principles common to both include flexibility, core stability, and strength training. A key element, especially in young athletes, is ensuring they get enough rest to allow for physiologic adaptation.

Fundamentals

In a growing system, flexibility is one of the most important and correctable biomechanical imbalances. Because bones grow in length, but muscles largely stretch to accommodate, most young athletes lack appropriate flexibility [19]. This can result in an increased frequency of traumatic muscle injury (strain), or overloading the tendon-bone anchor (apophysitis, eg, Osgood-Schlatter disease). A thorough stretching program should be part of every young athlete's training regimen. I usually discuss the fundamentals, then refer them to one of the excellent monographs on stretching for individual sports, such as Bob Anderson's book *Stretching* [20••].

Similarly, many young athletes attempt to gain a competitive edge by strength training. Unfortunately, the increased muscular force that results places more stress on muscles and tendons than they're prepared to handle. Also, as muscles grow in bulk (hypertrophy) they actually shorten, further limiting flexibility. Core stability training, on the other hand, should be part of every athlete's program. The trunk musculature provides a foundation for every movement of the extremities [21•]. "You can't fire a cannon out of a canoe" is a simple way I relate this principle to athletes and parents. Sit-ups, crunches, and the plank/bird dog positions discussed above are good methods of core training.

Many pediatric sports medicine specialists recommend weight training only for rehabilitation of injuries, or "toning" muscles at 70% maximal lifting until the age of 18 [22]. The two ways to train muscle are as individual units, or part of a functional complex. Isolated strengthening of a muscle group works well for the rotator cuff and shoulder stabilization, but usually lacks the neuromuscular integration, that characterizes sports. Functional training also has the advantage of simplicity, reducing complex motion to the three basic components of pulling or pushing with the upper extremity, and leg press

(squat) with the lower. Body Pump by Les Mills (Toronto, Ontario, Canada) [23], is one system that achieves total body fitness by combining these simple exercises with a core stability program.

Exercise physiology

For endurance athletes, flexibility and core strength remain the cornerstones of a training program, but it is also essential to understand the fundamentals of exercise physiology. Muscle can burn fuel to produce work with either aerobic (in the presence of oxygen), or anaerobic (fermentation) metabolism. Although aerobic exercise is very efficient, anaerobic metabolism consumes large amounts of fuel and produces lactic acid, a byproduct that is known to reduce muscular effort. The variable that determines which system will be used is the intensity of effort. When exercising on a treadmill, if the workload is slowly increased, several observations can be made. The amount of oxygen consumed, is linearly proportional to exercise intensity. Fortunately, so is heart rate, which is significantly easier to measure. The intensity at which metabolism becomes mostly anaerobic (anaerobic threshold) is roughly 70% to 80% maximal oxygen uptake (VO_2max) or heart rate. Although either of these limits can be determined on a treadmill, maximum heart rate is often estimated (for untrained individuals), by subtracting the athlete's age from 220 (accuracy $\pm 5\%$) [24•].

A discussion of specific training techniques is certainly beyond the scope of this article, but there are certain principles that are universal. Athletes should begin with 6 to 8 weeks of long, slow workouts (60%–70% maximum heart rate) to develop an aerobic base. Skipping this phase, due to the natural energy of youth, is a common mistake in young athletes. Following the principles of stress/rest/recover/adapt, athletes next increase VO_2max , then raise anaerobic threshold, so they can work as close to that maximum as possible without becoming anaerobic. The last system to develop is lactic acid tolerance, to help muscles metabolize this waste product, when brief bouts of anaerobic activity are required (sprinting to pass an opponent, or hill climbing).

The ancient Greeks were the first to recognize periodization, or separating their training into seasons [25]. These can be further divided into macrocycles, representing a full year and microcycles, typically weeks or months. A training year consists of the off-season, a month of rest and repair; precompetitive season, in which strength training and technique are emphasized; and the competitive season, varying in length for different sports. Microcycles typically involve alternating hard and easy workout sessions 5 or 6 days a week, then a full day of rest, for recovery. In sports with a specific event, such as the marathon, tapering becomes a consideration. Approaching the date of competition, training is slowly reduced to allow for more recovery, in preparation for an intense effort. The details of a taper depend upon the length of the event.

Special training

Certainly, training is sport specific, but there are two advanced techniques that deserve consideration for many athletes. Since the implementation of Title IX legislation in 1972, which guaranteed (somewhat) equal opportunity for females to participate in sports, the incidence of anterior cruciate ligament (ACL) injuries in women has greatly exceeded that of men [26]. Several possible factors include smaller ligaments, the effects of estrogen, and increasing competition without adequate coaching. Regarding the latter, women who jump tend to land with the knee extended, as opposed to men who practice soft landing. There are several programs, such as the Santa Monica ACL Injury Prevention Project [27], and Sportmetrics from Cincinnati Sports Medicine [28], designed to teach women proper jumping mechanics. They combine specific training in flexibility, strength, plyometrics, and proprioception, to decrease the risk of ACL injury.

Similarly, young pitchers and other throwers, often experience rotator cuff pathology, because too much attention is placed on developing the pectorals, deltoids, and other prime movers of the shoulder. Isolated rotator cuff strengthening is accomplished with the elbow held to the side, and the forearm flexed to 90°. Grasping resistance bands or a weight-pulley system, perform 25 internal rotations, followed by 25 external rotations, maintaining good form and speed. Eccentric training of the shoulder external rotators is accomplished by slowly returning the arm to the starting position, after an external rotation effort. Generally, relaxation of a muscle group should require about twice as long as the active, contraction phase. This eccentric strengthening helps the external rotators to slow the arm down after a pitch, and prevents anterior impingement with the coracoacromial ligament. Usually two or three sets of internal and external rotation are alternated during a training session. To complete the advanced training of serious athletes, we include visits with a nutritionist, and sport psychologist.

Finally, sports governing bodies have taken it upon themselves to restrict certain activities, based on the age of the athlete, to prevent injury. For example, the US Cycling Federation limits gear ratios for junior racers to 48 × 17 for ages 10 to 12, 48 × 16 for ages 13 to 14, and 48 × 15 for 15- to 16-year-olds. Similarly, The American Sports Medicine Institute recommends no more than 50 pitches per game for 9- to 10-year-old players, then 75 per game until age 15. Other popular strategies include limiting the number of innings pitched, or batters faced. It is also recommended that young athletes throw only fast balls, leaving the breaking ball pitches to high school and beyond [29]. In Australia, organized running follows a similar age-dependent progression, allowing a 5K at age 12, 10K at 14, half-marathon at 15 to 16, and full marathon for 18 years and above. These prohibitions, developed largely from experience, are a practical example of prehabilitation. Obviously, the organizations realized they could help

prevent repetitive motion injury, if young athletes were restricted from activities and techniques that are beyond their stage of physical development.

Conclusions

Great athletes may be born, and not made, but having favorable genetics does not guarantee a career in sports. I believe that many gifted, young individuals succumb to injury from poor training, coaching, or some correctable biomechanical imbalance. It is no longer sufficient to simply provide medical and orthopedic screening in a preparticipation physical examination. Even without the benefit of a comprehensive sports medicine center, primary care physicians can perform simple biomechanical assessment and fitness testing, then refer to a network of coaching specialists when advanced evaluation is required. Hopefully this discussion of prehabilitation will be useful in preparing young athletes for sports participation. By preventing avoidable injury, they may realize their full athletic potential, and enjoy a lifetime of fitness.

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